Cement remnants removal in implant restorations: A preliminary *in vitro* study

Treball de final de grau

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1. ABSTRACT

1.1. Spanish version

Objetivos: Evaluar la eficacia de la sonda metálica de exploración, del hilo dental encerado y de la cureta de teflón en la eliminación de restos de cemento en prótesis fija sobre implantes; Valorar si existen alteraciones en la superficie del pilar protético después de la utilización de estos instrumentos.

Material y Método: Estudio preliminar *in vitro* donde se utilizaron 9 coronas unitarias idénticas sobre implantes (incisivo central superior), fabricadas con tecnología CAD/CAM. Tras el proceso de cementación con cemento de óxido de zinc eugenol, cada corona fue aleatorizada a uno de los 3 grupos experimentales, en función del instrumento utilizado para la remoción de los excesos de cemento (cureta de teflón, sonda metálica de exploración e hilo dental encerado). Un investigador experimentado procedió a la remoción de los restos de cemento. Posteriormente, un investigador cegado evaluó la cantidad de cemento residual utilizando una inspección visual directa, fotografías digitales estandarizadas de las coronas (a gran aumento) e imágenes de microscopia electrónica de barrido (MEB). En este último análisis (MEB a 75 aumentos), también se evaluó la presencia de alteraciones en la superficie del pilar originadas por los instrumentos. Se realizó un análisis estadístico descriptivo.

Resultados: Después del cementado, fueron detectados restos de cemento en todas las áreas estudiadas. El instrumento que retiró un mayor porcentaje de restos de cemento fue la sonda metálica de exploración (59.4%) y el menor porcentaje el hilo dental encerado (27.6%). La sonda metálica de exploración produjo rayaduras en el 100% de las muestras (5 a 10 rayaduras identificadas en cada muestra).

Conclusiones: Aunque se observaron excesos de cemento en todos los grupos de estudio, la sonda metálica de exploración y la cureta de teflón parecen ser los instrumentos más eficaces. Dado que la sonda metálica de exploración produjo rayaduras en la superficie lisa del pilar protético, la cureta de teflón parece ser el instrumento más adecuado para retirar cemento en restauraciones sobre implantes. El hilo dental presentó un bajo nivel de remoción de cemento y dejó residuos, razón por la cual, no parece ser un dispositivo adecuado para esta indicación. Para confirmar los resultados de éste estudio preliminar, será necesario ampliar la muestra.

1.2. English version

Objectives: To evaluate the efficacy of stainless steel explorers, waxed dental floss and teflon scalers in removing cement remnants from fixed implant restorations; To evaluate if these instruments produce surface alterations in the abutment surface.

Materials and Methods: A preliminary *in vitro* study, involving 9 identical single-unit implant-supported crowns (upper central incisor), manufactured with CAD/CAM technology, was perfomed. After cementation with a zinc oxide eugenol cement, each crown was randomly allocated into 3 study groups, according to the instrument used to remove the cement remnants (teflon scaler, stainless steel explorer and waxed dental floss). An experienced professional removed the cement remnants. Afterwards, a blinded researcher evaluated the presence of cement using direct visual observation, standardized digital photographs and Scanning Electron Microscopy (SEM) images. In the latter analysis (SEM 75x), surface alterations in the abutment surface caused by the employed instruments were also registered. A descriptive analysis of the data was performed.

Results: After cementation, cement remnants were observed in all samples. The instrument that eliminated a higher percentage of cement remnants was the stainless steel explorer (59.4%) and the worst, the waxed dental floss (27.6%). The stainless steel explorer produced scratches in 100% of the samples (5 to 10 scratches in each sample).

Conclusions: Even though cement debris was observed in all samples, stainless steel explorers and teflon scalers seem to be the most effective instruments in the removal of cement remnants in implant-supported restorations. Since stainless steel explorers scratched the abutment surface, teflon scalers seem to be the best option for this particular indication. Dental floss is not a suitable alternative since it removed less cement than the other 2 instruments, and also left some material debris (small threads) over the abutment. A larger sample is required to confirm the present findings.

2. INTRODUCTION

One of the most suitable options to replace teeth are implant-supported restorations. In general, dental implants placed under favorable conditions, are considered to be long-term highly predictable therapy with a success rate ranging 95%, after 15 years of follow-up[1].

However, this treatment is not free of complications, which may be technical, biological and/or aesthetic[1]. A special mention should be made to peri-implant diseases (mucositis and peri-implantitis), which are complex and multifactorial.

Most studies estimate that around 10% of implants and 20% of patients will develop peri-implantitis, 5 to 10 years after implant placement[2]. A similar range has also been reported in a private practice environment in Spain. Indeed, Mir-Mari et al.[3], estimated that 12 to 22% of patients with dental implants have peri-implantitis.

Several risk factors for peri-implantitis have been suggested. Smoking habit, inadequate oral hygiene and previous history of periodontitis are considered to be strong risk indicators[4]. However, genetic factors[5], implant surface characteristics[6], systemic conditions such as diabetes[7] or HIV[8] and the type of restoration (screwed or cemented)[1] may also play an important role.

Cement-retained crowns have become popular because of their simple use, passive fit, better aesthetics and occlusion control. In addition, these restorations can be used systematically, since the angulation and position of the implant are less critical, allowing greater tolerance during the surgical placement and the procedure is similar to conventional fixed restorations[9]. Moreover, some authors such as Korsch and Walther[10], report more complications with screwed prosthesis in comparison with cemented ones.

Nevertheless, cement-retained implant restorations also have drawbacks. To date, several authors have established a correlation between cement excess and the presence of peri-implant diseases (shown in 81-85% of implants with cement remnants), especially in patients with a history of periodontal disease[11–13]. In addition, it has been seen that, if the cement is removed, the disease symptoms may disappear in most cases[12]. Thus, cement remnants might be considered initiating factors for peri-implant diseases[14].

It is important to highlight that cement excess or remnants, are those that can be seen macroscopically but also small particles that can be clinically undetected. In this regard, the position of the restoration margin respect to the gingival level plays a crucial role: in deep subgingival margins, undetected cement is a common finding[15].

Several techniques have been proposed to reduce the excess of cement. External cementation techniques, cementation in two steps or precementation, have been reported to be superior to the conventional technique[9,16–21].

Several instruments, such as dental explorers, metal or plastic scalers, dental floss, and others have been used to remove cement remnants in the daily clinical practice[11,15,16,20–25]. However, few data has been published to determine which is the most suitable instrument for this purpose. Agar et al.[22] compared three instruments (stainless steel explorer, plastic and gold scaler), but obtained inconclusive results. However, these authors have raised a very interesting issue, since, in some occasions, scratches caused by the instruments could be found in the abutments.

3. OBJECTIVES AND HYPOTHESIS

3.1. Objectives

3.1.1. Main objectives

- **Objective 1:** To determine the efficacy of teflon scalers, stainless steel explorers and waxed dental floss to remove cement remnants from single-tooth implant-supported restorations.
- **Objective 2:** To evaluate if the above-mentioned instruments (teflon scalers, stainless steel explorers and waxed dental floss) produce alterations in the abutment surface of single-tooth implant-supported restorations.

3.1.2. Secondary objectives

- **Objective 3:** To quantify the amount of cement remnants that are detectable after the cementation process in implant-supported crowns.

3.2. Hypothesis

3.2.1. Main hypothesis

- **1 H_0:** Stainless steel explorers, teflon scalers and waxed dental floss are equally effective in the removal of cement remnants from single-tooth implant-supported restorations.
- **1 H_1:** Stainless steel explorers are more effective than teflon scalers and waxed dental floss to remove cement remnants from single-tooth implant-supported restorations.
- **2 H_0:** None of the employed instruments (stainless steel explorer, teflon scaler and waxed dental floss) will cause any alteration in the abutment surface of single-tooth implant-supported restorations.

- **2 H_1:** The use of stainless steel explorers to remove cement remnants will cause scratches in the abutment surface of single-tooth implant-supported restorations.

3.2.2. Secondary hypothesis

- **3 H_0:** Cement remnants will not be detectable in the abutment area adjacent to the restoration margin, after the cementing process.
- **3 H_1:** Cement remnants will occupy approximately 4 mm^2 of the abutment area adjacent to the restoration margin, after the cementing process.

4. MATERIAL AND METHOD

4.1. *In vitro* model

An aluminium template made with Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) technology (Mozo-Grau, Valladolid, Spain) was employed in the present *in vitro* study. This template included 3 implant analogues separated by a 3 mm margin. The replicas were 1.5 mm apart from the buccal and lingual/palatal margin (Annex Figures 1, 2, Annex Table 2). These three analogues represented implants in the following positions: 1.1, 2.1 (test) and 2.2. Two screw-retained crowns were fabricated for the mesial and distal implants (1.1 and 2.2) (Annex Figure 3, Annex Table 2), and 9 identical cement-screw restorations were made using a 1-mm-height polished abutment for the centrally positioned implant 2.1 (Figure 1). A combined screw and cement retained crown design (Figures 2, 3) was chosen in order to allow unscrewing the entire crown-abutment complex without touching the cement remnants. The adjacent restorations (1.1 and 2.2) were added to the template to mimic a more realistic clinical scenario with interproximal areas. Both, 1.1 and 2.2 crowns were screw-retained again to facilitate the removal of the test restoration without affecting the cement excesses (Figures 4, 5) (Annex Figure 4).

The template, abutments and crowns were specifically manufactured for this study by Mozo-Grau® (Mozo-Grau, Valladolid, Spain) according to specifications made by the researchers. All specifications of study template and dimensions can be found in Annex Table 2 and Annex Figures 1 to 4.

An artificial polyvinylsiloxane gingiva (GI-MASK automix®, Coltene, Altstätten, Switzerland) was fabricated by a dental technician (Fco. Javier Fernández SL. Dental prosthesis laboratory, Barcelona, Spain) by means of a wax-up (Figure 6). Crowns margin were placed in 1 mm subgingival position. One gingiva replica was used for each sample to avoid damage by use.

All the material employed in this preliminary *in vitro* study was listed in Annex Table 1.

The study crowns (2.1) were randomly assigned into three study groups (Table 1): teflon scaler (TS) (Figure 7), stainless steel explorer (SE) (Figure 8) and waxed dental floss (DF) (Figure 9).

Figure 1. Implant abutment.

Figure 2. Test crown (buccal view).

Figure 3. Test crown (palatal view).

Figure 4. Study template with 1.1, 2.1 and 2.2 crowns (buccal view).

Figure 5. Study template with 1.1, 2.1 and 2.2 crowns (palatal view).

Figure 6. Study template with artificial gingiva (buccal view).

Figure 7. Detail of teflon scaler.

Figure 8. Detail of stainless steel explorer.

Figure 9. Detail of waxed dental floss.

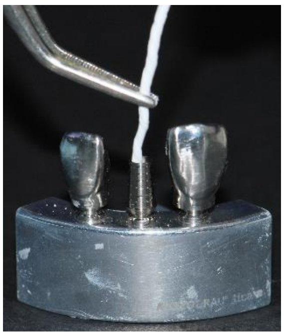

Figure 11. Placement of teflon in the abutment (buccal view).

Figure 12. Teflon placed in the abutment (oclusal view).

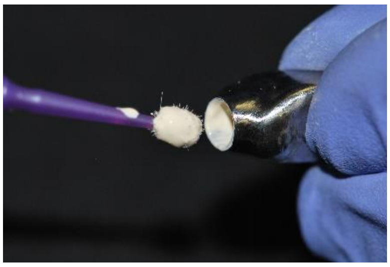

Figure 13. Placement of cement with a microbrush.

Figure 14. Cementation process. Finger pressure to cement.

Figure 15. Cement excess removal with a teflon scaler.

Figure 16. Cement excess removal with a stainless steel explorer.

Figure 17. Cement excess removal with waxed dental floss.

Table 1. Groups distribution.

Group	Instrument	Abutments / Crowns
TS	Teflon scaler	S2, S3, S8
SE	Stainless steel explorer	S4, S5, S9
DF	Waxed dental floss	S1, S6, S7
TS, teflon scaler; SE, stainless steel explorer; DF, waxed dental floss; S, sample		

Briefly, the sequence of the study was as follows for each sample: the 2.1 crown was cemented and **"Analysis 1: Evaluate the amount of cement excess, after cementation"** was performed by direct visual observation and digital photographic analysis. Then, the cement remnants were removed and **"Analysis 2: Evaluate the amount of cement remnants to compare the instruments use, after removing cement remnants"** was performed by direct visual observation and digital photographic analysis. In a separate session, the third part of Analysis 2 was done with a Scanning Electron Microscope (SEM) (Quanta 200®, FEI, Hillsboro, Oregon, United States). Also, a SEM was also employed for **"Analysis 3: Evaluate abutment surface alteration caused by instruments, as a secondary effect"** (Figure 10). Each step and each analysis method is explained in detail below (sections 4.2 – 4.7).

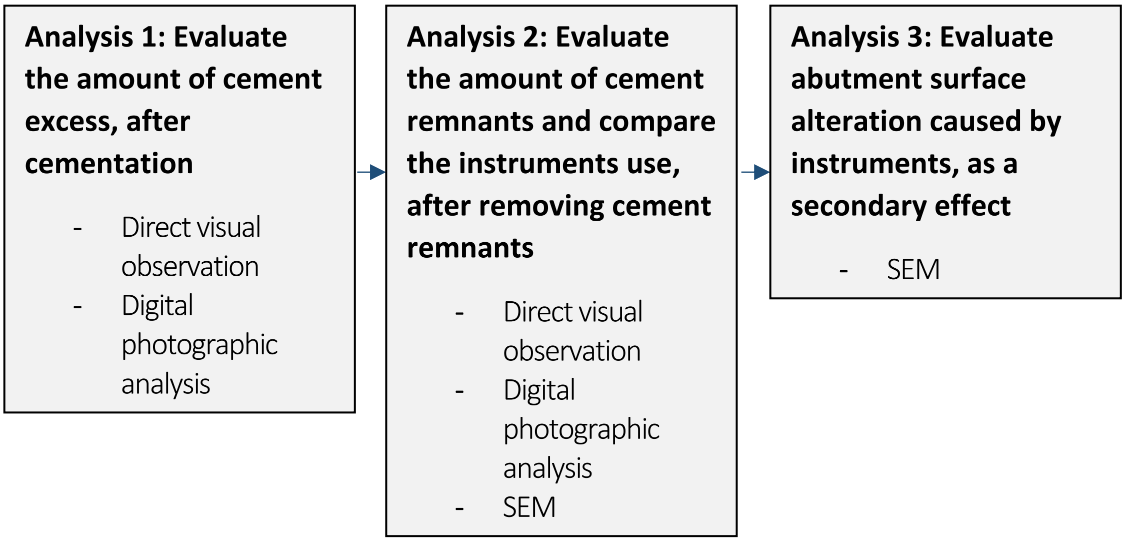

Figure 10. Study analysis sequence.

4.2. Cementation process

After placing the abutment in the 2.1 analogue, a piece of teflon was inserted into the screw hole, to avoid the entrance of cement (Figures 11, 12). Next, the crown perforation was covered superficially with composite, to avoid cement to flow through this hole. Later, the two components of the zinc oxide eugenol cement (Temp Bond®, Kerr Corp, Orange, United States of America) were mixed with the cement spatula on the mixing pad for 1 minute and 30 seconds according to the manufacturer instructions.

The cement was applied with a microbrush (Figure 13) and the crown was then fitted on the abutment, and pressure was applied by the operator for 7 minutes (Figure 14).

Once the setting time elapsed, composite and teflon were removed in order to unscrew the abutment-crown complex.

The first analysis was then carried out: "**Analysis 1: Observation of cement excess after cementation**" by direct visual observation of each quadrant (buccal, mesial, palatal and distal). The abutment-crown complex was placed back and the second part of Analysis 1 was performed, in which a standardized digital photography using a macro lens was taken. The specifications of the different methods of analysis can be found in sections 4.4, 4.5 and 4.6 of the text.

4.3. Cement remnants removal

A second operator (experienced clinician), who had not been involved in the cementation process, generated a random allocation sequence with blocks in the webpage http://www.randomization.com, assigning one instrument to each sample. Subsequently, the cement remnants were removed with the respective instruments (Figures 15-17) without a specific time restriction in order to simulate a more real scenario. This procedure was performed with 2.3x magnification loupes (Exam-Vision, Copenhagen, Denmark) for greater precision. The area was then rinsed with a water and air spray for 1 minute.

The crown was removed again to perform the second analysis: **"Analysis 2: Comparison of the instruments use after removing cement remnants",** first by means of direct visual observation and secondly by digital photographic analysis, after placing the crown back in the study template after removing the artificial gingiva. The specifications of the different methods of analysis can be found in sections 4.4, 4.5 and 4.6 of the text.

4.4. Direct visual observation analysis

Analysis 1 was performed with naked eye at a span eye-object distance. Analysis 2 was performed with 2.3x magnification loupes. Each sample field (buccal, mesial, palatal and distal) was observed searching for cement (Yes/No).

4.5. Digital photographic analysis

With digital photographs, Analysis 1 and 2 were carried out. All the photographs, in both analyses, were taken in a standardized manner using a digital camera (Nikon D60®, Nikon, Tokyo, Japan) with a macro lens AF-S VR Micro-Nikkor 105 mm f/2.8G IF-ED (Nikkor Lens®, Nikon, Tokyo, Japan). The following parameters were used: diaphragm aperture f/20; exposure time of 1 second and a focal distance of 105 mm.

Subsequently, the digital photographs were edited with Windows 10 Photo Viewer® (Microsoft Corporation, Washington, United States) to the following measurement: 285x128, selecting as area of interest the entire abutment height collar (that is 1 mm) plus 0.8 mm of the adjacent crown zone. In addition, the contrast and brightness of the images were adjusted, with the same software, to facilitate the analysis.

Next, the areas with cement remnants were selected by freehand selection tool of ImageJ® software (NIH, Maryland, United States). All areas (in mm^2) with cement remnants on each quadrant were added separately and included in the database to calculate the cement remnants area and cement remnants reduction percentage (Figures 18-20).

4.6. Scanning Electron Microscopy (SEM) images analysis

The samples were stored in a plastic box at room temperature, and transported carefully to Scientific and Technological Centers of the University of Barcelona (*Centres Científics i Tecnològics de la Universitat de Barcelona*: CCiTUB, Barcelona, Spain) to perform the third part of Analysis 2 and the Analysis 3.

A Scanning Electron Microscope (SEM) Quanta 200® (FEI, Hillsboro, Oregon, United States) was employed. Microscope working parameters were: Everhart-Thornley Detector (ETD), High-Voltage (HV): 20,000 kV, Working Distance (WD): 7.4 to 15.6 mm.

Images were taken at 75x, 100x, 200x and 500x, selecting as area of interest the center of each quadrant, placing the objective on the center of crown-abutment margin.

In order to differentiate cement remnants from other residues, a chemical analysis was carried out, obtaining a spectrophotometry. An identification of the main chemical elements of the zinc oxide eugenol cement was made and compared with the areas were the cement remnants were allegedly located.

A 75x magnification was used for both cement remnants identification (Analysis 2) and for surface alterations detection (Analysis 3).

Once again, cement area selection of each image was made using freehand selection tool of ImageJ® software (NIH, Maryland, United States) as previously described.

For Analysis 2, cement remnant areas of less than 0.001 mm^2 were discarded. All areas (in mm^2) with cement remnants on each quadrant were added separately and included in the database to calculate the total cement remnants area.

For Analysis 3, those scratches with less than 0.150 mm of length were discarded. The presence or absence of scratches was detected, evaluating as "yes" or "no" and counting the number of scratches in each area.

4.7. Statistical analysis

The random sequence was kept in an opaque envelope during the entire data analysis, so that the researcher remained blinded for the study groups throughout the procedure.

A descriptive analysis (mean and standard deviation (SD)) was used to report data. Due to the small sample size and to the nature of this study (preliminary report), bivariate analysis was not performed.

5. RESULTS

A total of 9 samples (3 samples for each group) were analysed. The following results were obtained, according to the different analysis methods:

5.1. Direct visual observation analysis

Seven of the 9 samples had an excess of cement in all observed areas (buccal, mesial, palatal and distal). In 2 of them, 50% of the studied areas had no cement (after the artificial gingiva was removed).

Concerning Analysis 2 (after removing the cement remnants and the artificial gingiva), made with 2.3x magnifying loupes, 33.3% of the samples had cement on all areas, 55.6% had cement on some areas and 11.1% had no cement at all. Interproximal areas (mesial and distal) had cement in 77.8% of cases, whereas buccal (66.7%) and palatal (55.6%) zones had slightly less cement remains.

5.2. Digital photographic analysis

Regarding Analysis 1, a 100% of the samples had cement remnants in all the areas. On average, each sample had 7.4 ± 2.35 mm^2 on its surface covered with cement (Table 2).

Analysis 2, showed an average cement area of 4.34 ± 5.26 mm^2. When comparing the 3 study groups, the following outcomes were registered: teflon scaler group: 1.47 ± 0.16 mm^2; stainless steel explorer group: 2.51 ± 0.41 mm^2; dental floss group: 9.04 ± 7.75 mm^2. The higher percentage of cement remnants removal was found in the stainless steel explorer group (59.4%), followed very closely by the teflon scaler group (58.3%). The instrument that performed worst was the waxed dental floss, which only eliminated 27.6% of the remnants (Figures 18-22, Table 2). Therefore, none of the instruments achieved the complete removal of the cement.

The areas in which the instruments were more effective were the mesial surface of the abutment for the teflon scaler group (mean percentage of reduction: 47.7%); the distal aspect for the stainless steel explorer group (61.7%) and the buccal area for the dental floss group (35.1%).

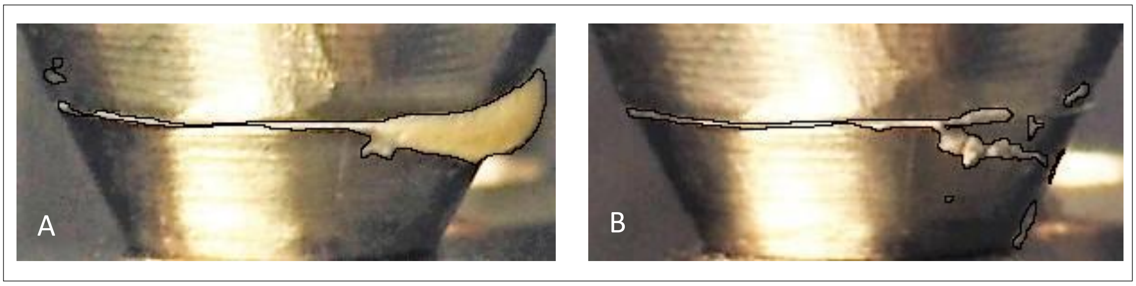

Figure 18. Digital photographs with cement remnants area selected with ImageJ® software. TS group (sample 2, mesial area). A, Time 1; B, Time 2.

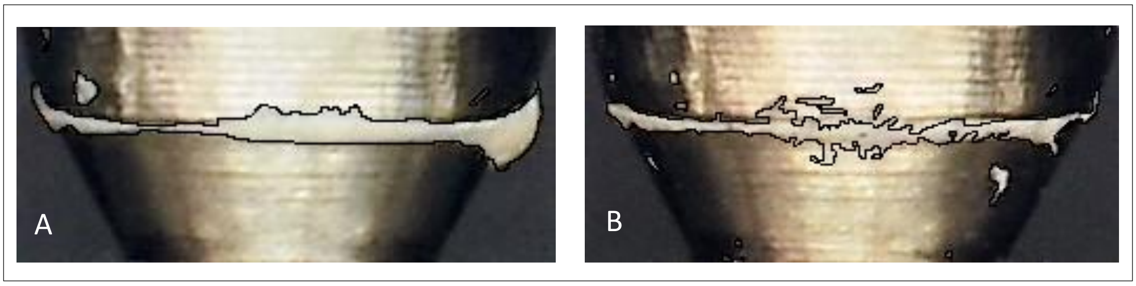

Figure 19. Digital photographs with cement remnants area selected with ImageJ® software. SE group (sample 9, palatal area). A, Time 1; B, Time 2.

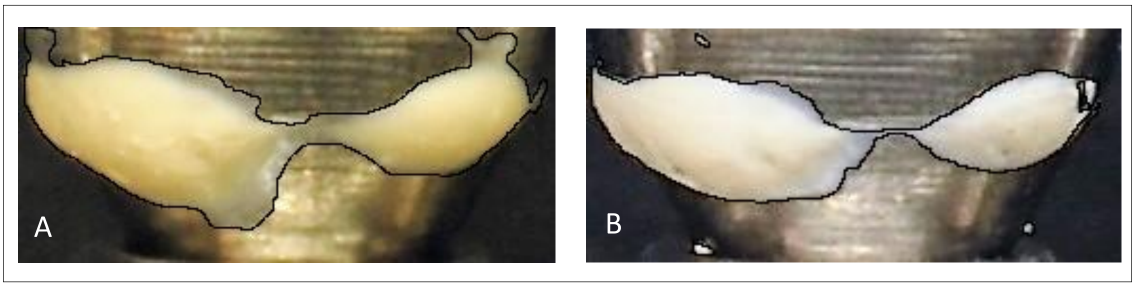

Figure 20. Digital photographs with cement remnants area selected with ImageJ® software. DF group (sample 7, buccal area). A, Time 1; B, Time 2.

Table 2. Digital photographic analysis results.

Instrument	Abutment	Before removing CR (T1) (mm^2)	After removing CR (T2) during 2 min and 27 sec on average (mm^2)
TS	A1 (S2)	2.82	1.33
	A2 (S3)	1.07	1.65
	A3 (S8)	6.71	1.44
	Mean ± SD	**3.53 ± 2.97**	**1.47 ± 0.16 (-) 58.3%**
SE	A1 (S4)	3.77	2.09
	A2 (S5)	9.23	2.51
	A3 (S9)	5.53	2.92
	Mean ± SD	**6.18 ± 2.79**	**2.51 ± 0.41 (-) 59.4%**
DF	A1 (S1)	1.06	1.16
	A2 (S6)	25.06	16.65
	A3 (S7)	11.31	9.31
	Mean ± SD	**12.48 ± 12.04**	**9.04 ± 7.75 (-) 27.6%**
TOTAL Mean ± SD		**7.39 ± 2.35**	**4.34 ± 5.26**

TS, teflon scaler; SE, stainless steel explorer; DF, dental floss; A, abutment; S, sample; CR, cement remnants; T1, time 1; T2, time 2; min, minutes; sec, seconds; (-), reduction

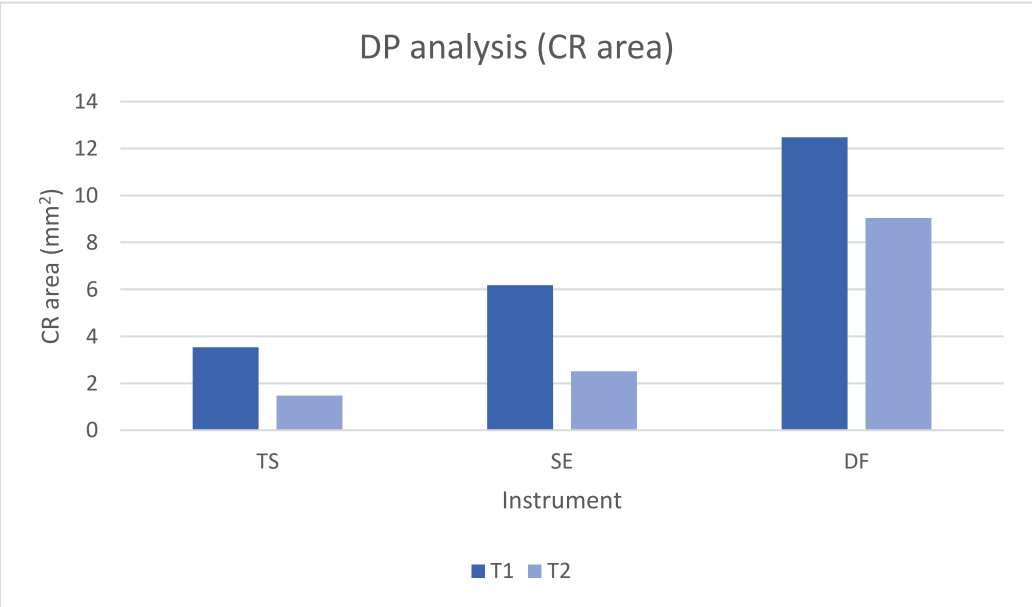

Figure 21. Digital photographic analysis (cement remnants area). DP, digital photography; CR, cement remnants.

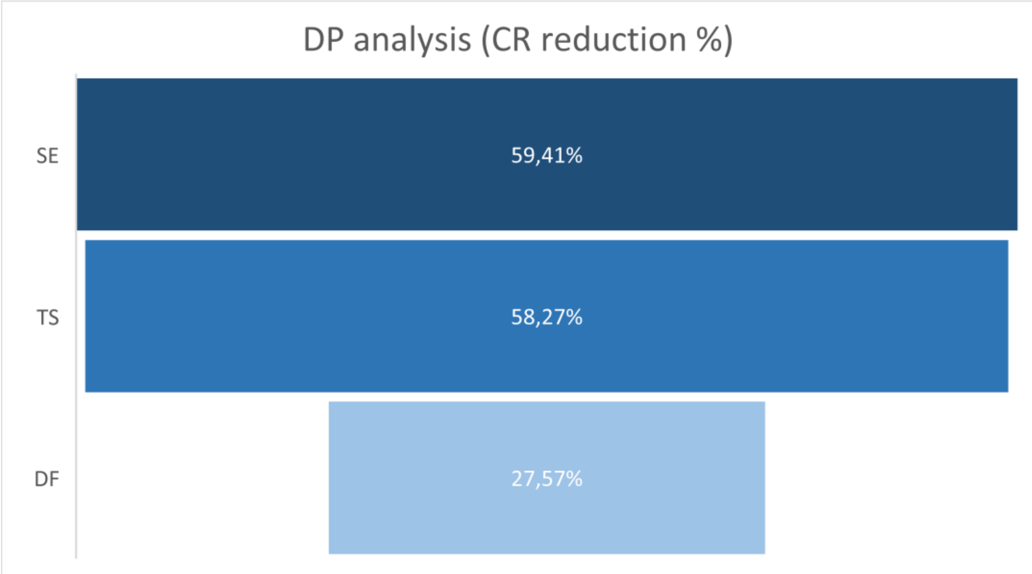

Figure 22. Digital photographic analysis (cement remnants reduction percentage). DP, digital photography; CR, cement remnants; SE, stainless steel explorer; TS, teflon scaler; DF, dental floss.

5.3. SEM analysis

Regarding the analysis made with SEM (75x magnification) after cement removal, the following results were found: the teflon scalers had a mean cement area of 1.02 ± 0.46 mm^2; the stainless steel explorer group presented 2.83 ± 0.33 mm^2 of remnants and the dental floss group 10.62 ± 8.85 mm^2. The average area for all groups was 4.82 ± 6.26 mm^2 (Figure 23, Table 3).

Only stainless steel explorers produced surface irregularities in 100% of the abutments of its group (SEM 75x), since 5 to 10 scratches were found on each sample. They can be described as long and deep (Figure 24). Teflon scalers and dental floss did not produce visible alterations to the abutment surface (SEM 75x). However, dental floss fragments were found in 2 of the 3 samples of this group (Figure 25).

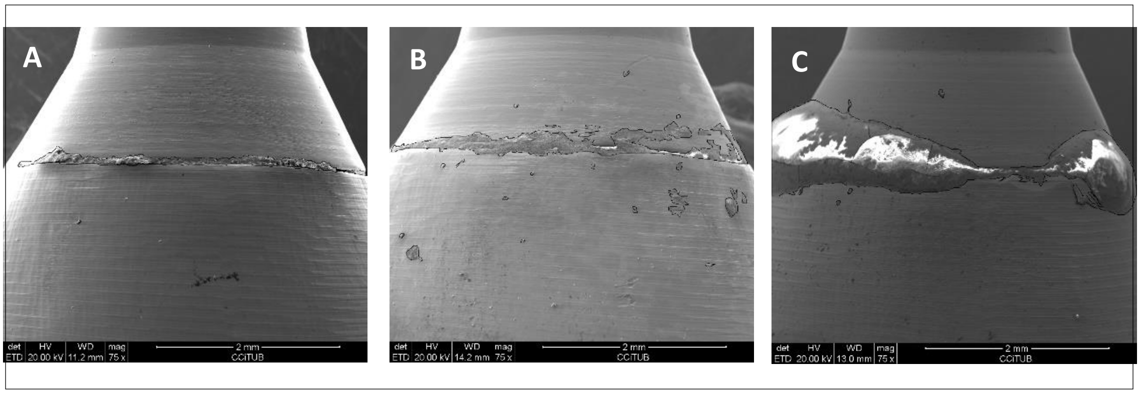

Figure 23. SEM images (at 75x). A, TS group (sample 2, distal area); B, SE group (sample 9, mesial area); C, DF group (sample 7, mesial area). Cement remnants area selected by ImageJ® software.

Table 3. SEM analysis (cement remnants area and scratches).

		After removing CR (T2)	
Instrument	Abutment	CR area (mm^2)	Scratches (number) / IR
TS	A1 (S2)	0.84	No
	A2 (S3)	0.68	No
	A3 (S8)	1.53	No
	Mean + SD	**1.02 + 0.46**	**-**
SE	A1 (S4)	2.52	Yes (5-10)
	A2 (S5)	3.17	Yes (5-10)
	A3 (S9)	2.79	Yes (5-10)
	Mean + SD	**2.83 + 0.33**	**-**
DF	A1 (S1)	0.70	No / IR
	A2 (S6)	17.73	No / IR
	A3 (S7)	13.41	No
	Mean + SD	**10.62 + 8.85**	**-**
TOTAL Mean + SD		**4.82 + 6.26**	**-**
TS, teflon scaler; SE, stainless steel explorer; DF, dental floss; A, abutment; S, sample; CR, cement remnants; IR, instrument remnants			

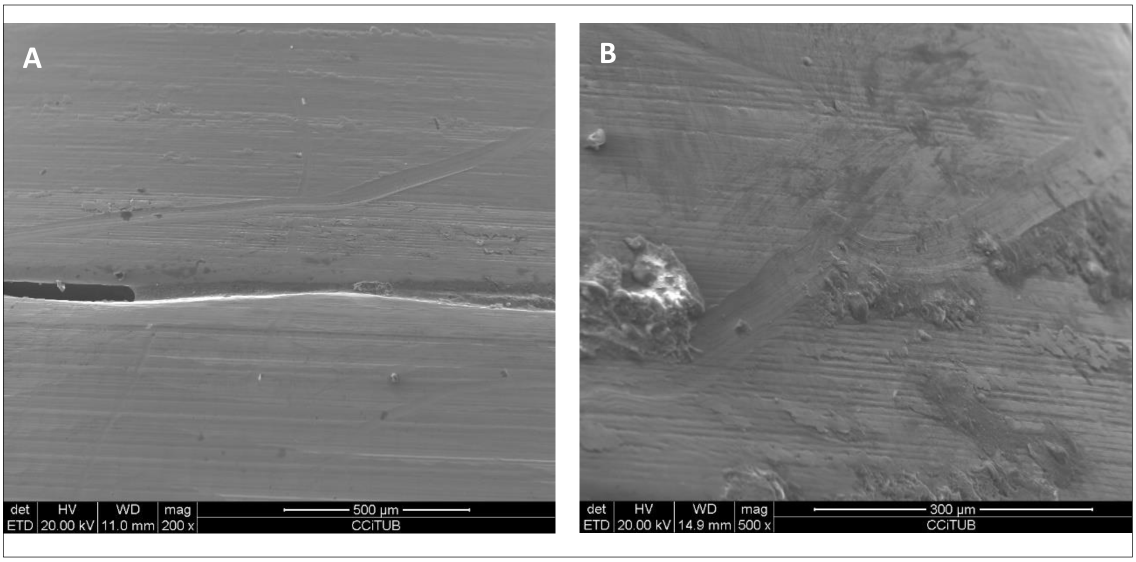

Figure 24. SEM images (at 200x and 500x) showing surface alterations produced by the study instruments. A: SE group, sample 4, buccal area; B: SE group, sample 9, mesial area.

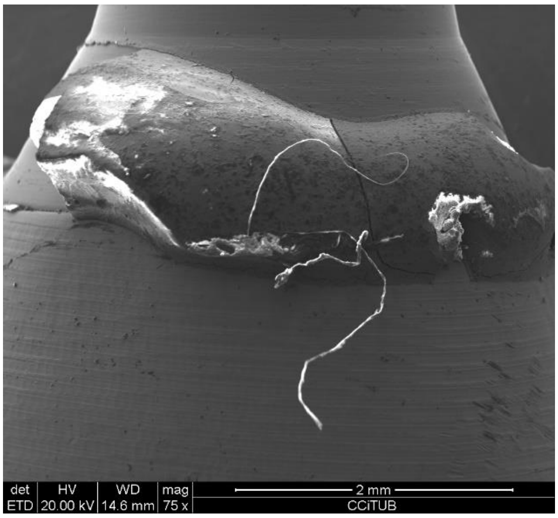

Figure 25. 75x SEM image showing a dental floss fragment. DF group, sample 6, mesial area.

6. DISCUSSION

The main objective of the present investigation was to compare the efficacy of three different instruments to remove cement excess from the abutment surface. Many authors have linked the presence of cement remnants with the initiation of peri-implant diseases[4,14,16].

6.1. Key results

According to the digital photographic analysis, the average amount of cement that flowed into the subgingival area after cementation was of 7.4 ± 2.4 mm^2. In the present study, all instruments allowed a decrease in this area, with the best results being obtained in the stainless steel explorer (1.5 ± 0.2 mm^2) and teflon scaler (2.5 ± 0.4 mm^2) groups. These areas were slightly different when measured using SEM (1.0 ± 0.5 mm^2 of cement remnants after removal in teflon scaler group; 2.8 ± 0.3 mm^2 in stainless steel explorer group and 10.6 ± 8.9 mm^2 in dental floss group). This difference might be explained due to the positioning of the samples during the SEM analysis. In the digital photographic analysis, all photographs were made in a totally standardized manner, allowing calculating an approximate total area with cement (sum of 4 areas: mesial view, distal view, buccal view and palatal view). The same methodology could not be precisely reproduced when using the microscope, and this might have led to some disagreement between the 2 analyses. Nonetheless, the outcomes were quite similar, and again, stainless steel explorer and teflon scaler groups performed much better that dental floss samples.

The best instruments in terms of cement removal capacity were the stainless steel explorer (reduction of 59.4%) and the teflon scaler (reduction of 58.2 %). On the other hand, the waxed dental floss showed a disappointing result of only 27.6% of cement excess removal. Although the main study aim was to determine which instrument had a higher efficacy in removing cement remnants, other variables should also be considered when selecting the most appropriate instrument for this purpose. Indeed, alterations to the polished and smooth surface of the abutment should be avoided at all costs, since producing scratches and irregularities might lead to a higher biofilm adhesion in these areas. Stainless steel explorers produced 5 to 10 scratches in all the samples of its group and therefore should be used with caution. Teflon scalers probably produced very small irregularities (in fact, some very thin threads could be seen at SEM with 200x magnification) but its clinical relevance might be very low.

6.2. Cement excess after cementation

Cementing a crown is a technically-demanding procedure[22] that depends on several factors. The type of cement[10,13,24,26], the cementation technique[9,16,20,27], the margin location respect to the gingival level[15] and margin type of the abutment[16,28] are variables that must be taken into account. For example, low viscosity cements (methacrylate based cement) have been associated with higher probability of leaving remnants[10,24].

Recently, multiple techniques to reduce cement excess after cementation have been proposed with good results. Indeed, methods like the use of an abutment replica[9,16,27], or making holes in the palatal face of the crown[20,27] have been proven to be effective.

Linkevicius et al.[15] evaluated the relation between the margin location and the presence of cement retained and concluded that deep subgingival margins (valued up to 3 mm), are more difficult to clean. Also, chamfer abutment finish lines[16] and concave emergence profiles[28] increase the risk of cement remnants presence.

Other authors propose alternative methods, such as removing the cement remnants immediately after crown placement, using foam pellets to remove it. Once cleaned, a glycerol gel can be placed on the margins, and the professional should apply constant vertical pressure on the crown[28].

6.3. Cement remnants after excess cement removal

The results of the present preliminary trial are relatively comparable to the ones reported by Agar et al.[22] for the stainless steel explorer group. These authors described an area that could reach up to 1.7 ± 3.5 mm^2, whereas we have described a value of 2.8

± 0.3 mm^2. This difference could be due to the fact that Agar et al.[22] based their results on the observation through an optical microscope (20x magnification), while our examination was made with a SEM (75x magnification).

6.4. Instruments for removing cement remnants: Efficacy and surface alterations

Stainless steel explorers (59.4%) and teflon scalers (58.2%) had the best results in the present *in vitro* study, although these were clearly disappointing. Indeed, an experienced clinician was unable to adequately remove the cement remnants even though he had no time limit for such procedure (in average, 2 minutes and 27 seconds were spent for each crown).

On the other hand, dental floss had the worst outcomes, with a reduction of only 30% of the cement area. Moreover, dental floss left countless threads attached to the cement and abutment area (Figure 25). According to van Velzen et al.[29], such remains, may represent a risk factor for peri-implant diseases since they can lead to an inflammatory foreign body reaction.

To our knowledge, Agar et al.[22] paper, is the only one that compared different instruments to remove cement remnants in implant-supported restorations. These authors evaluated a stainless steel explorer, a plastic scaler and a gold scaler with no major differences among groups. Other instruments like superfloss[15,16,30], ultrasonic plastic tips[16], gold scalers[22], plastic scalers[22,24] and scalpel blades[20] have also been proposed. However, as its effectiveness has not been evaluated, it can not be said whether this perform better.

Although most dental professionals use stainless steel explorers to remove cement[15,16,21–25,30], the present study suggests that the same outcome could be expected with the use of teflon scalers. The latter have the advantage, of producing less surface alterations. Similar findings were reported by Agar et al.[22], since stainless steel explorers were also associated with the presence of scratches in the abutment surface. On the other hand, teflon scalers are more difficult to place inside of the gingival sulcus (due to its bulky active part) and are more fragile.

6.5. Study limitations

The major limitations of this research project were the limited sample size and its *in vitro* nature. Although many efforts have been made to reproduce a real clinical scenario (no time limit for the clinician, the use of artificial soft tissue, real crown anatomy, reproduction of interproximal areas by introducing adjacent crown into the study template, etc.), *in vitro* studies might lack some external validity. In consequence, the results should be interpreted with caution, especially due to the small number of crowns on each group. In contrast, the present study allowed standardizing both the design of abutments and crowns, the type of cement, the cementing technique or the cement removal technique. In other words, this *in vitro* design allowed limiting the influence of possible confounding variables.

One of the main objectives of preliminary studies is to identify possible methodological issues. In fact, one of the main difficulties found during the cementation of the crowns was to standardize the amount of cement were used. Has proposed by Begum et al.[27], insulin syringes, but the cement density ruptured the syringe plunger. So, the authors decided to replicate the methodology of Sancho-Puchades et al.[28] and used a microbrush to apply a uniform layer of cement. In future investigations, the use of extraoral systems[9,16–21] or of automatic pipettes should be considered in order to reduce initial disparities between groups.

Another drawback is related with the area measurement of the cement remnants. Since volume and weight of cement were not assessed, the data analysis is more complex since, in some occasions after the use of the instrument, a smaller amount of cement might be dispersed over a larger area, therefore compromising the reliability of the results.

The lack of concordance between cement remnants areas in the digital photographic and SEM analysis could be related with the difference in image resolution and magnification. SEM images have a high resolution and allow distinguishing details perfectly, while digital photographs were more challenging to assess. Undeniably, when the photograph was enlarged, the cement remnants limits were difficult to determine.

Finally, surface alterations are tricky to evaluate, since thin scratches might be produce by the machining process of the abutment or by small impacts received during the shipping process. Future research should try to solve this limitation by introducing control abutments.

6.6. Clinical applicability of the results

The instruments that have been used to remove cement remnants are generally ineffective. In our study, although the stainless steel explorers and teflon scalers had better results when compared to dental floss, they left roughly 40% of cement remnants in the abutment. In addition, stainless steel explorers scratched the abutment surfaces and dental floss left threads of material in the samples, which are two possible risk factors for peri-implant tissues inflammation[29].

In our opinion, this study alerts clinicians that most instruments are not effective in removing cement and that some might even damage the abutment.

It is important to stress that biofilm can easily attach to a rough cement area or irregular surfaces. This in conjunction with a limited accessibility to the submucosal region might be crucial for peri-implant diseases development. Therefore, it is very important to use an effective and safe instrument that is able to remove cement remnants without affecting the abutment surface.

6.7. Implications for future research

Firstly, this preliminary study will allow to design a new *in vitro* research with a larger sample (a power calculation will be made) and with less methodological issues, in order to determine which of the 3 tested instrument is more effective and safe.

Secondly, there is very limited data on the efficacy of other instruments used for cement removal in implant-supported restorations. Thus, the same design can be used again but now testing other instruments. Also, the use of chemical removing agents like bio orange solvent[16] might be interesting to test.

Other variable that might be interesting to investigate is the operator's clinical experience, because the results may vary significantly between clinicians.

Eventually, if all the tested devices show to be inadequate, there might be a need to design and develop a new instrument.

7. CONCLUSIONS

7.1. Spanish version

Con las limitaciones del presente estudio preliminar *in vitro*, se pueden plantear las siguientes conclusiones:

A pesar de que se observaron residuos de cemento en todas las muestras, las sondas metálicas de exploración y las curetas de teflón parecen ser los instrumentos más eficaces en la remoción de restos de cemento en restauraciones soportadas por implantes. Dado que las sondas metálicas de exploración rayaron la superficie del pilar, las curetas de teflón parecen ser la mejor opción para esta indicación en particular. El hilo dental no es una alternativa adecuada, ya que eliminó menos cemento que los otros 2 instrumentos, y también dejó algunos restos materiales (pequeños filamentos) sobre el pilar. Se requiere una muestra mayor para confirmar los presentes hallazgos.

7.2. English version

Within the limitations of the present preliminary *in vitro* study, the following conclusions can be drawn:

Even though cement debris was observed in all samples, stainless steel explorers and teflon scalers seem to be the most effective instruments in the removal of cement remnants in implant supported restorations. Since stainless steel explorers scratched the abutment surface, teflon scalers seem to be the best option for this particular indication. Dental floss is not a suitable alternative since it removed less cement than the other 2 instruments, and also left some material debris (small threads) over the abutment. A larger sample is required to confirm the present findings.

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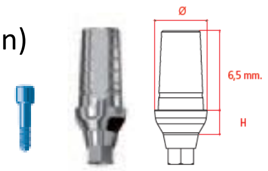
9. ANNEX

9.1. Employed materials

Annex Table 1. Employed materials.

Study template
- 1 CAD/CAM aluminium model (Mozo-Grau, Valladolid, Spain)
- 3 stainless steel implant analogues (inHex®, Mozo-Grau, Valladolid, Spain) - Platform: 2.80 mm - Diameter (ø): 4.0 mm
- 11 1-mm-height hexagonal titanium grade V ($TiAl_6V$) implant abutments (inHex®, Mozo-Grau, Valladolid, Spain) - Platform: 2.80 mm - Ø: 4 mm - Screwdriver: 1.25 hexagonal 
- 2 CAD/CAM type 4 Cr-Co alloy screwed crowns (Mozo-Grau, Valladolid, Spain)
- 9 CAD/CAM type 4 Cr-Co alloy cemented crowns (Mozo-Grau, Valladolid, Spain)
- 9 Polyvinylsiloxane (addition-type) artificial gingivas (GI-MASK automix®, Coltene, Altstätten, Switzerland)
Experimental groups
- Stainless steel explorer (Maillefer, Ballaigues, Switzerland)
- Waxed dental floss (Vitis®, Dentaid, Cerdanyola, Barcelona, Spain)
- Teflon implant scaler (Kerr Corp, Orange, California, United States)
Necessary and auxiliary materials for experimentation
- Zinc oxide eugenol (ZOE) (Temp Bond®, Kerr Corp, Orange, California, United States)
- Cement spatula
- Cement mixing pad
- 9 Microbrushes (Microbrush, Grafton, Wisconsin, United States)
- Polytetrafluoroethylene (PTFE) high density tape
- Mayo scissors
- Contra-angled tweezers

- Composite (Tetric EvoCeram®, Ivoclar Vivadent, Schaan, Liechtenstein)
- Composite spatula
- Marker
- Compartmentalized plastic box
- 2.3x magnifying loupes (Exam-Vision, Copenhagen, Denmark)
Photography
- Nikon 60® digital camera (Nikon, Minato, Tokyo, Japan) - Macro lens AF-S VR Micro-Nikkor 105 mm f/2.8G IF-ED (Nikkor Lens®, Nikon, Tokyo, Japan)
Microscopy
- Scanning electron microscope (Quanta 200®, FEI, Hillsboro, Oregon, United States)

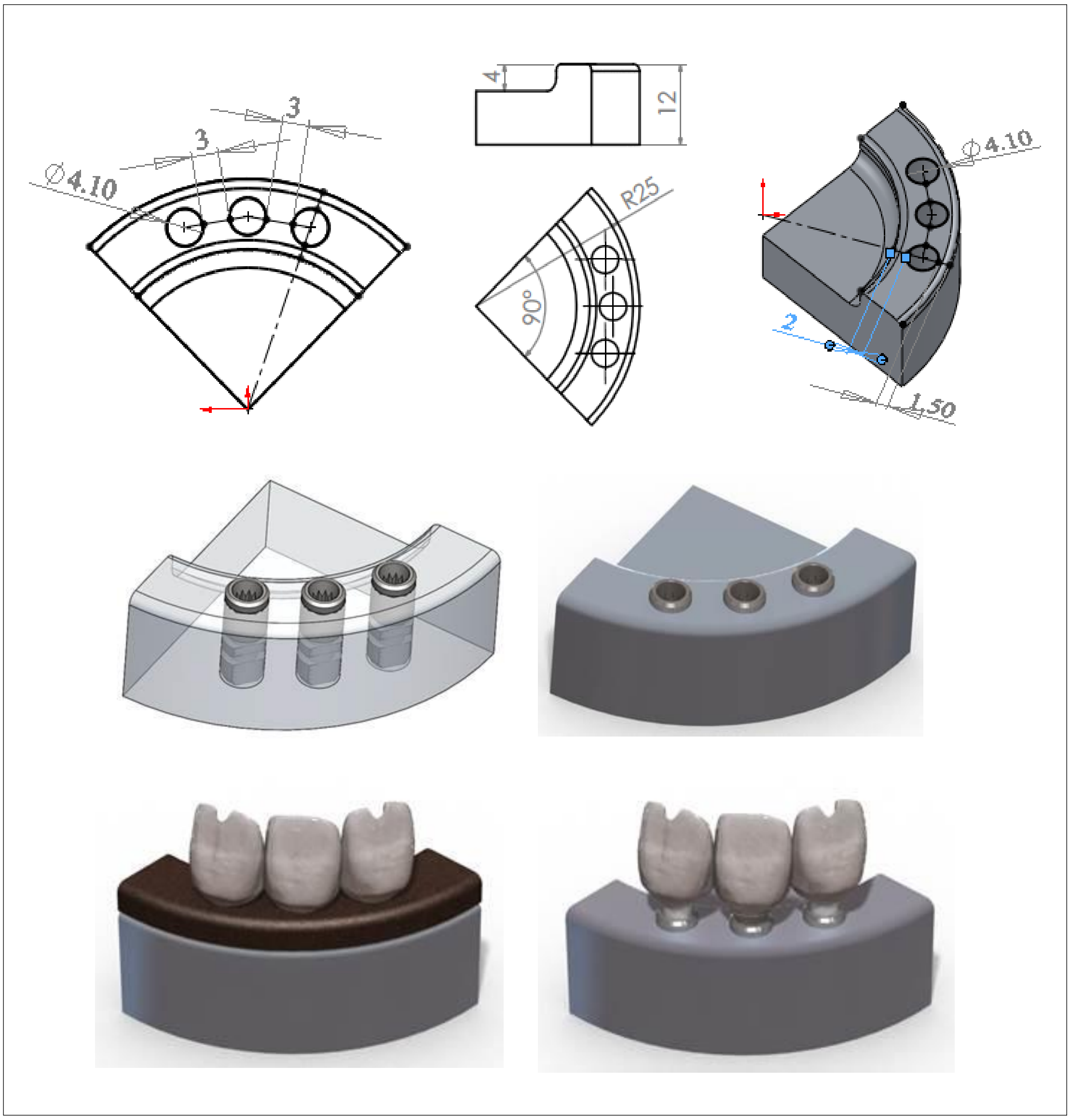
9.2. Study template parameters

Annex Table 2. Study template and crowns parameters.

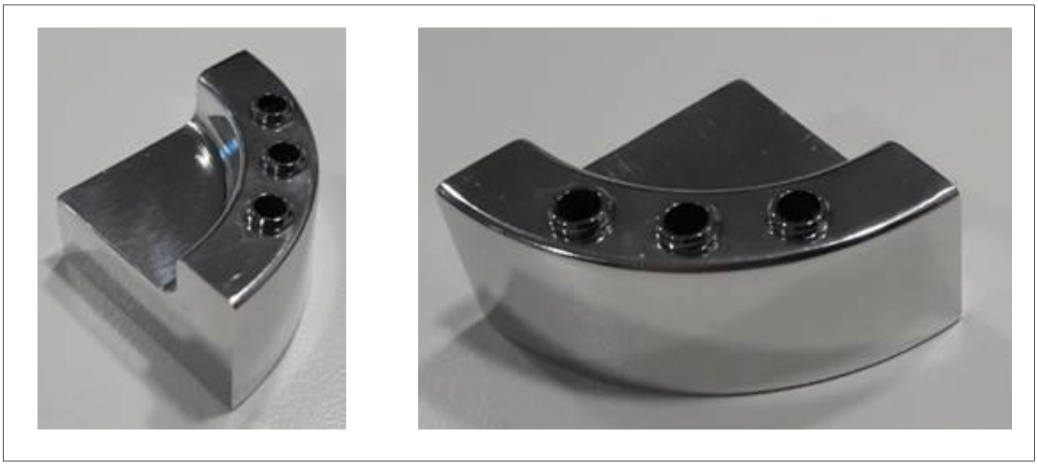
Study template
- Distance between implants: 3 mm
- Analogues ø: 4.10 mm
- Distance to buccal plate: 1.5 mm
- Distance to palatal plate: 1.5 mm
- External dimensions: 25 x 25 x 12 mm
Crowns
Space for cement
- Thickness: 0.055 mm
- Start: 0.5 mm
- End: 0 mm
Margin
- Horizontal: 0.15 mm
- Oblique: 0.1 mm

-	Angle: 65º
-	Vertical: 0.05 mm
-	Low margin: 0 mm
-	Drilling compensation (bur ø): 0.01 mm.

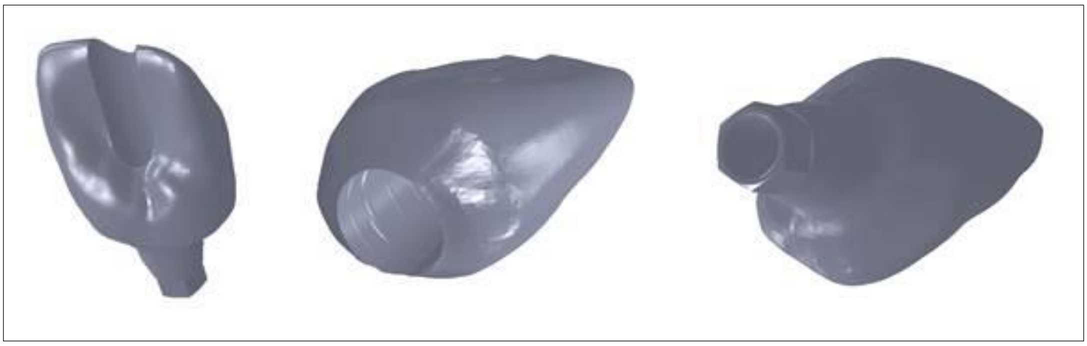
Annex Figure 1. Study template design and parameters.



Annex Figure 2. Study template manufactured (without abutments and crowns).



Annex Figure 3. Crowns design.



Annex Figure 4. Study template and crowns manufactured (without artificial gingiva).